Operational Flexibility Modeling In the 2014 LTPP, R.13-12-010

Sasha Cole & Patrick Young

Generation & Transmission Planning, Energy Division
California Public Utilities Commission, Auditorium

June 6, 2014, 10am – 4pm

Remote Access

WebEx Information:

Meeting number: 747 724 548
Meeting password: ltpp

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Workshop Communications

In person attendees, please:

- Ask questions at the wireless microphones near the front of the auditorium
- Announce your name and organization before speaking

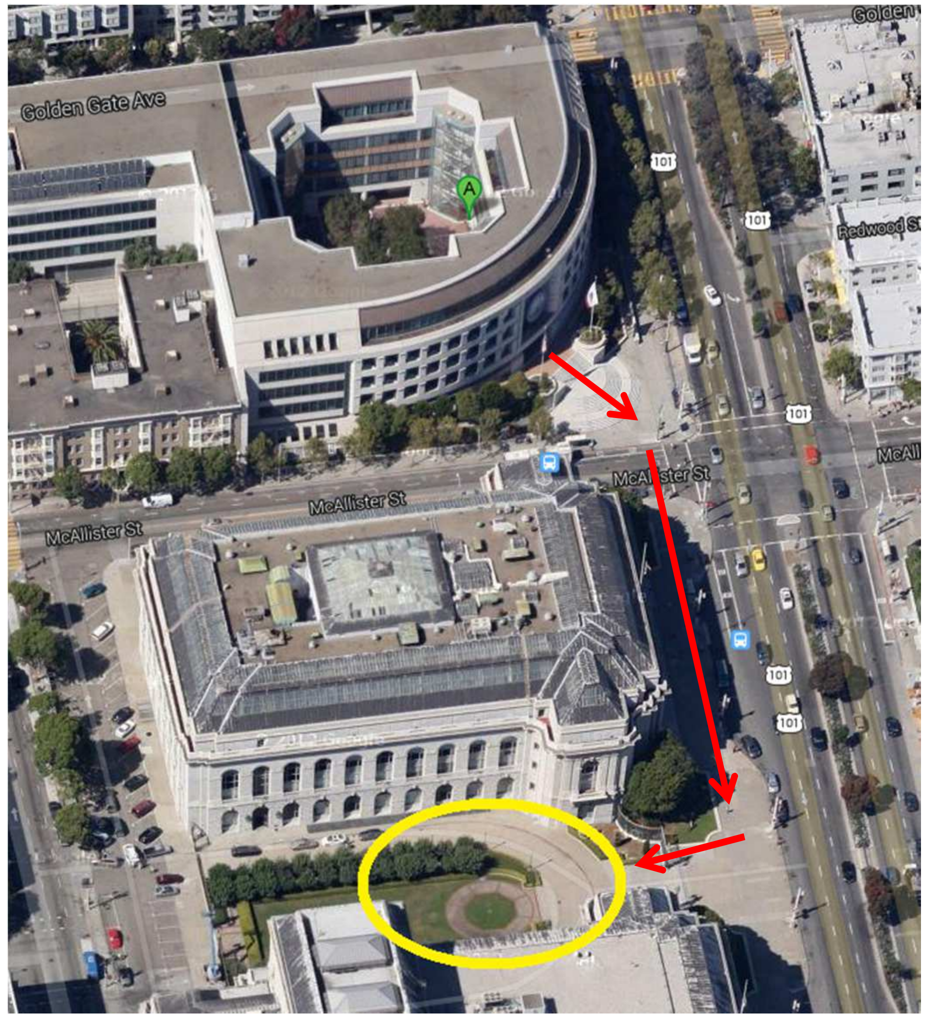
Remote attendees, please:

- Upon entry to the call, place yourself on mute (*6 to mute/unmute)
- We will invite callers to ask questions during the course of the workshop. During those times, remain on mute unless you are actively asking a question.
- Announce your name and organization before speaking.
- Interact with the workshop via the phone if you have a pressing question or technical difficulty. Webex chat will not be monitored frequently.
- For technical difficulties that cannot be conveyed over the phone, contact Patrick Young at patrick.young@cpuc.ca.gov

Restrooms & Evacuation Procedure

Restrooms are out the Auditorium doors and down the far end of the hallway.

In the event of an emergency evacuation, please cross McAllister Street, and gather in the Opera House courtyard down Van Ness, across from City Hall.



Key Milestones

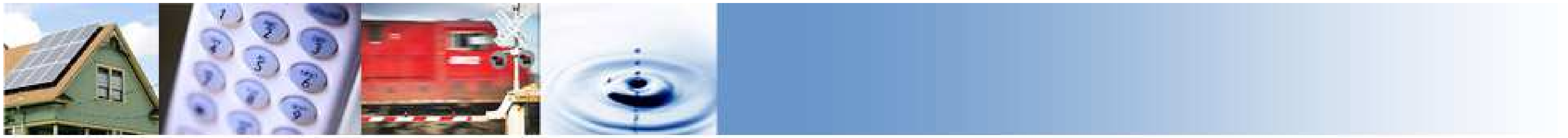
ACR on Planning Assumptions originally issued	February 27, 2014
Workshop on comparing operational flexibility models and stochastic model result reporting metrics	April 24, 2014
Scoping Memo and Ruling	May 6, 2014
ACR on Planning Assumptions technical updates issued	May 14, 2014
ALJ Ruling on Phase 1a/1b issues and scheduling	June 2, 2014
Workshop on modeling parties’ operational flexibility methodologies	June 6, 2014
Testimony of parties preparing models	August 13, 2014
Testimony of parties not preparing models	September 3, 2014
Reply testimony (all)	September 24, 2014
Last date to request evidentiary hearings	September 24, 2014

Workshop Purpose

- In this workshop, the modeling parties (SCE and CAISO) will inform other parties about the details and complexities of their respective technical models to study grid operational flexibility needs in 2024
- The goal is to increase transparency and equip parties with the information needed to interpret modeling results and prepare written testimony to inform the CPUC LTPP Proceeding (R.13-12-010) Phase 1a determination of system need

Agenda

Time	Speaker	Topic
10:00 – 10:15	Patrick Young, Energy Division	Introduction / Schedule
10:15 – 11:25	Megan Mao, SCE	Describe SCE's analysis objectives. Define Loss of Load event and Overgeneration event. Describe how to interpret result metrics such as heat maps, confidence intervals, and percentiles.
11:25- 12:10	Erin Childs, SCE	Introduce SCE's LTPP analysis model framework and principles. Define stochastic analysis and describe study objectives. Describe the model's implementation of overgeneration analysis. Describe the model's implementation of hydro generation.



Agenda

12:10 – 1:10		Lunch Break
1:10 – 1:45	Martin Blagaich, SCE	Define forecast error and describe the model's implementation of forecast error. Describe the model's use of sample stratification and how convergence in results will be demonstrated.
1:45 – 2:05	SCE	Discuss next steps and timeline for SCE's analysis. Q and A session.
2:05 – 2:15		Break
2:15 – 4:00	Shucheng Liu, CAISO	Discuss assumptions and data sources for the ISO deterministic model.

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System and Flexibility Analysis for the 2014 LTPP Phase 1A

Work in Progress

2014 Long Term Procurement Plan (LTPP)
R.13-12-010
June 2014

This presentation contains on-going work that is subject to change.
SCE is interested in all comments, questions, and recommendations, which can be sent to:
Megan.Mao@sce.com

SCE will perform stochastic analysis of system need for the year 2024 for Phase 1A of the 2014 LTPP.

Analysis Objectives

- Identify potential need for or surplus of resources in 2024 to meet system operational flexibility, or other system reliability requirements
- Evaluate other reliability challenges under future conditions (including over-generation, etc.)

Agenda

1. Result Metrics
2. 2014 LTPP Analysis
3. Next Steps and Timeline

Result Metrics

Result Metrics

- Loss of Load / Upward Need
- Over-Generation / Downward Need

The main deliverable of the analysis will be system deficiencies identified by calculating expected loss of load events.

Results Metrics

Expected Loss of Load Events

- Resource need is determined by the expected frequency of Stage 3 Emergency events or hours in the study year.
  - **Expected Events/Hours* in 10 Years:** The metrics for reporting how likely reliability violations are expected to occur
  - **Stage 3 Emergency:** When reserves drop below 3% of load and rotating outages are authorized to begin
  - **Outage Event:** Any day (24 hours period) with at least one hour of Stage 3 Emergency Conditions.
  - **Outage Hour:** Any hour across the year with Stage 3 Emergency Conditions

SCE's Phase 1A analysis will find the expected Stage 3 emergency events and associated resource need. Resource type will be determined in Phase 1B of the 2014 LTPP Proceeding.

*In the 2012 LTPP, an event was defined as any day that has a stage 3 emergency

Expected reliability events and associated confidence intervals should be used to determine if additional resources are needed.

System Need Result Types

System Need Results

- **Expected Events**
  Are the expected loss of load events acceptable?
- **Magnitude**
  How much shortfall reduction is needed to limit expected events to an acceptable level?
- **Confidence Intervals**
  How accurate is the expected events calculation?

Are additional resources needed?

Need Characteristics

- **Event Distributions (Heat Maps)**
  When are reliability violations expected to occur?

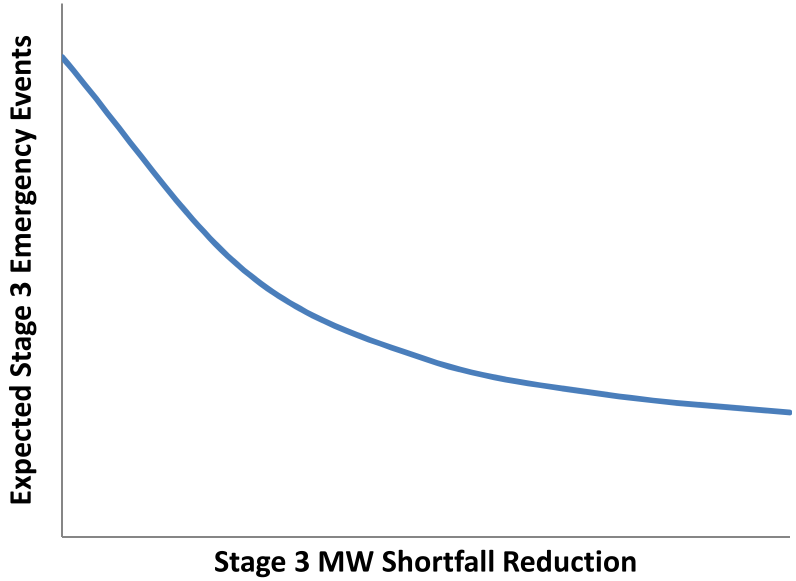
What do additional resources need to be capable of?

SCE will produce results to understand the tradeoff between reliability and additional resources.

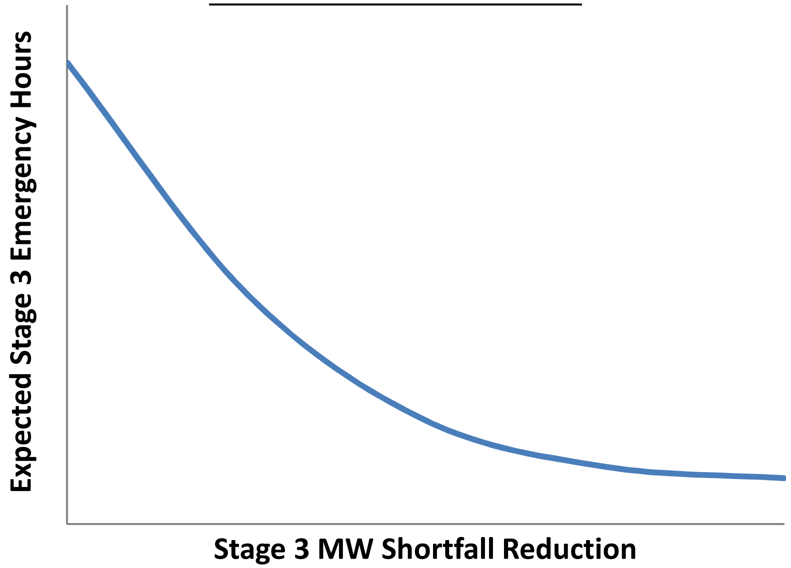
Results for Different Reliability Criteria

Illustrative Only

Outage **Events** vs Resource Need



Outage **Hours** vs Resource Need



SCE intends to use the 1-event-in-10-years standard as the metric for need determination

Confidence intervals and the expected value show the potential range of the most likely outcomes

Loss of Load – Expected Events and Confidence Intervals

Illustrative Only

		5th Percent Confidence Limit	Expected Value	95th Percent Confidence Limit
"Frequency of Need"	Expected Stage 3 Emergencies over 10 Years	1.00	1.24	1.49
"Magnitude of Need"	Shortfall Reduction Needed to Reduce Expected Events to 1* (MW)	0	300	500

In this example:

We are 90% confident that the correct estimate is between 1.00 and 1.49 events

The analysis estimates 1.24 events is expected to occur over 10 years, and 300 MW of resources are needed to achieve a 1-event-in-10-year reliability standard

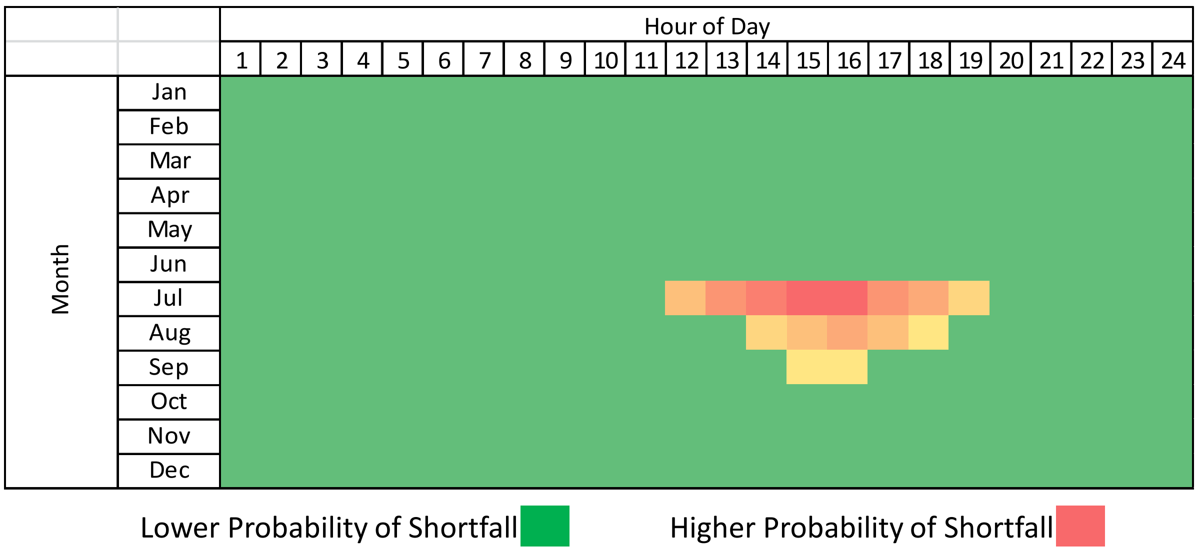
*Phase 1B will cover the type and amount of resources needed to reduce shortfall identified.

Heat maps will show the probability of events occurring within different time periods

Loss of Load - Heat Map

Illustrative Only

Stage 3 Emergency Heat Map (Probability of Stage 3 Emergency by Time Period)



In this example, Stage 3 Emergencies are most likely to occur during the Summer afternoon hours.

- Heat Maps will inform the characteristic of resources used to fill need – time of day, time of year
- Information is descriptive, as solutions that do not fit within identified time periods may still help reduce reliability violations

*Heat Map results do not necessarily inform duration

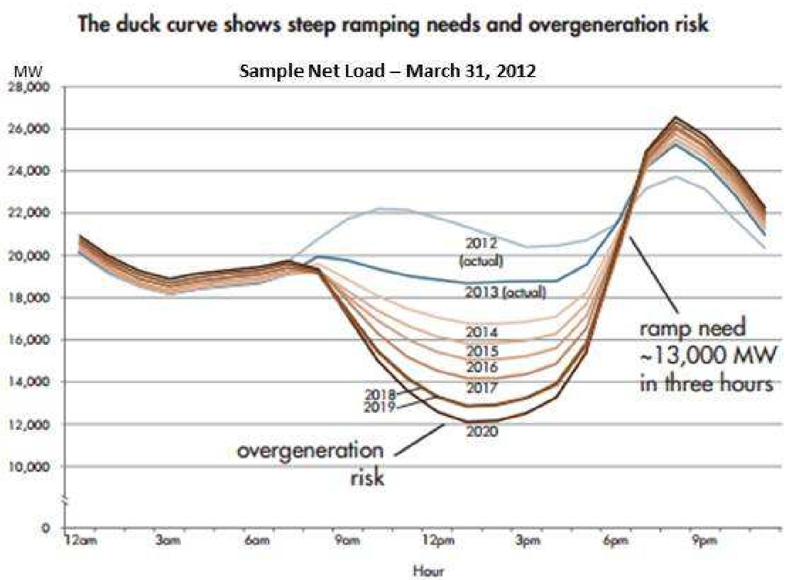
Result Metrics

- Loss of Load / Upward Need
- Over-Generation / Downward Need

The key purpose of studying over-generation is to understand the economic tradeoffs within the system

Over-Generation Overview

<u>CAISO "Duck Chart"</u>



(from the California Independent System Operator)

- Potential solutions to over-generation include:
  - <u>Export</u> of energy at a possible negative price
  - <u>Low / Negative Market Prices</u> to incent less generation or more load during stress hours
  - <u>Curtailment</u> of generation
  - <u>Storage</u> to shift energy to periods of higher demand
- The key purpose of studying over-generation is to understand the economic tradeoffs within the system

The characteristics of over-generation will determine the most economic solutions

Over-Generation Types of Results

Over-Generation Characteristics

- **Expected Events**
  How frequently is over-generation expected to occur?
- **Magnitude**
  How much reduction is needed to limit over-generation to an acceptable level?
- **Confidence Intervals**
  How accurate is the expected events calculation?
- **Event Distributions (Heat Maps)**
  When is over-generation expected to occur?

Since there is no defined acceptable level of Over-Generation occurrence, results will be presented to help understand the characteristics of Over-Generation.

Results will show the expected number of over-generation events and their magnitude during the study year.

Over-Generation Expected Events and Confidence Intervals

Illustrative Only

		5th Percent Confidence Limit	Expected Value	95th Percent Confidence Limit
"Frequency of Need"	Expected Over-Generation Events over 10 Years	1.00	1.24	1.49
"Magnitude of Need"	Over-Generation MW Reduction Needed to Reduce Expected Events to 0*	100	300	500
"Magnitude of Need"	Expected Over-Generation GWh*	20	40	60

- Events will be defined and calculated in the same method as Loss of Load, however, unlike loss of load there is not a standard reliability threshold that must be met.
- Magnitude of need is reported in two ways
  - The MW reduction needed to reduce expected events to 0*
  - The GWh needed to reduce over-generation events to 0*

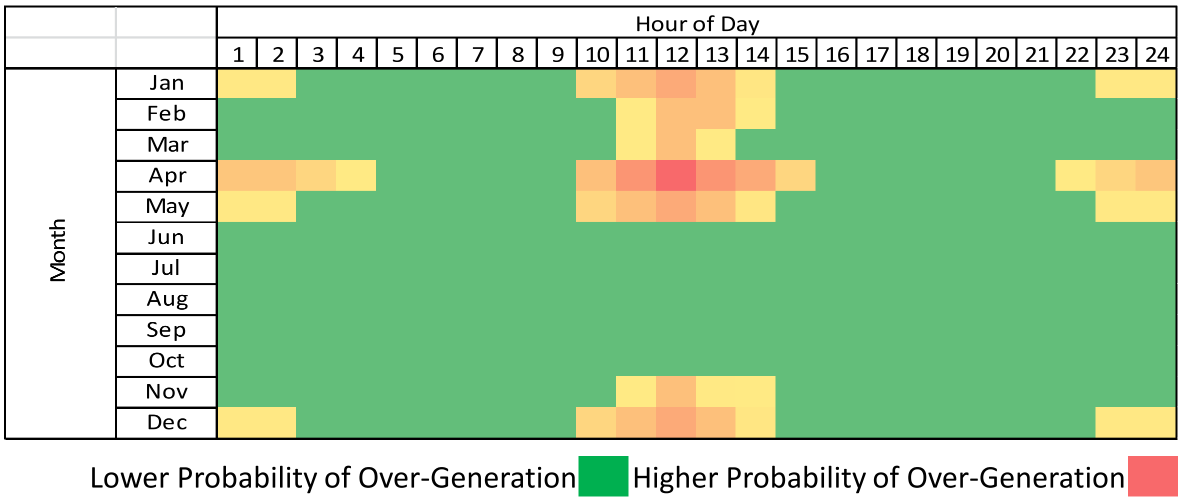
* Since there is no acceptable level of Over-Generation occurrence, results will be presented to help understand the characteristics of Over-Generation.

Heat maps will show the probability of events occurring within different time periods

Over-Generation Heat Map

Illustrative Only

Over-Generation Heat Map (Probability of Over-Generation by Time Period)



In this example, over-generation has the highest probability of occurring in the spring and winter mid-day periods.

- The Over-Generation Heat Map will inform the probability of over-generation occurring in different time periods.
- Information is descriptive, as solutions that do not fit within identified time periods may still help reduce reliability violations

*Heat Map results do not necessarily inform duration

Standard Reporting Metrics – To Be Determined

- In addition to the proposed metrics, SCE may also produce Standard Reporting Metrics that will be determined by the CPUC.

2014 LTPP Analysis

2014 LTPP Analysis

- Overview
- Over-Generation
- Hydro
- Net Load Following and Forecast Error
- Convergence Analysis

SCE will perform stochastic analysis of system need for the year 2024 for Phase 1A of the 2014 LTPP.

Analysis Overview

Analysis Objective

- Identify potential need for or surplus of resources in 2024 to meet system operational flexibility, or other system reliability requirements
- Evaluate other reliability challenges under future conditions (including over-generation, etc.)

Analysis Design Principles

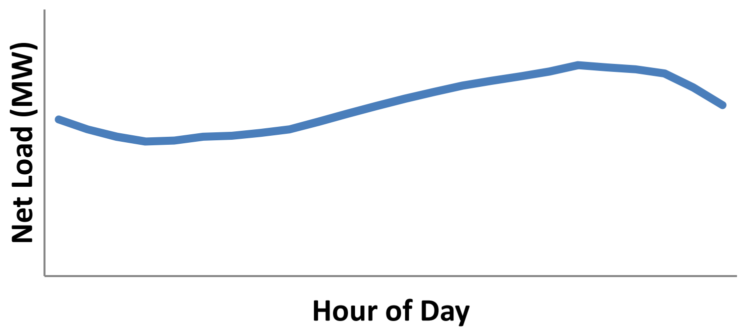
- Rely on publicly available information and standardized planning assumptions
- Generate realistic uncertainty in key variables
- Account for intra-hour flexibility with 5-minute granularity analysis
- Perform full unit commitment to capture generator's physical constraints
- Calculate loss of load probabilities and other reliability metrics to determine if new resources are needed to meet reliability standards

Stochastic analysis can capture and understand the inherent uncertainty in system reliability analysis.

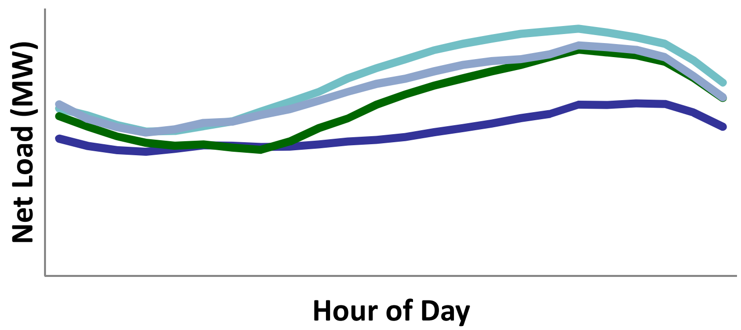
What is Stochastic Analysis?

Stochastic: Uncertain; Involving Chance or Probability

Deterministic Example



Stochastic Example



Purpose of Stochastic Analysis

- Consider realistic uncertainty of variable inputs
- Evaluate a wide range of possibilities
- Understand the likelihood of different outcomes

*Net load, defined as load minus wind and solar production, is just one of the inputs stochastically varied

SCE's analysis has changed compared to the 2012 LTPP stochastic analysis.

2014 LTPP Analysis Comparison*

Item	2012 LTPP CAISO Deterministic Analysis	2014 LTPP SCE's Analysis
Load, Intermittent Resources, and Generation Availability	Deterministic	Stochastic
Hydro Conditions	Deterministic	Stochastic
Dispatch Horizon	8760 Hours	One day for each month; but many samples
Dispatch Granularity	1 Hour	1 Hour
Economics	Full	Full
Forecast Error	Yes	Yes
CA Detailed Modeling (Generation, Transmission, Constraints)	Yes	Yes
WECC (ex CA) Modeling	Detailed	Simplified
Reliability Measure	Reserve / Load Shortfall	Reserve / Load Shortfall Probability

*Highlighted cells represent changes from SCE's 2012 LTPP Analysis

The study process will consist of input development, capacity analysis, and production simulation analysis.

Analysis Process Overview

Scenario Input Development

Develop the input assumptions, stochastic and deterministic, for the scenario.

Capacity Analysis

Determine if the system is short of capacity through traditional planning methods.

Simulation Modeling

Perform a stochastic analysis on the system using PLEXOS production simulations software.

Results Metrics

Calculate the expected system deficiencies and surpluses, along with other metrics.

Load, Wind and Solar Generation, Hydro Conditions, and Generation Outages will be treated as stochastic variables and based on the scoping memo assumptions.

Scenario Input Development

Stochastic variables will be based on the scoping memo assumptions*, and will be made stochastic based on historical or simulated data:

1. **CAISO Load** – Thirteen years of historical weather information is used to produce thirteen distinct 5-minute granularity load forecasts that represent 2024 potential load outcomes.

2. **CAISO Wind and Solar Generation** – One year of CAISO-simulated 2024 5-minute wind and solar generation is used to represent intermittent generation outcomes.

3. **CAISO Hydro Conditions** – 40+ years of historical hydro generation within CA is used to create a distribution of potential hydro conditions.

4. **CAISO Fleet Availability / Outages** – Forced and scheduled outage rates are used to create a distribution of potential fleet availabilities (same rates used in CAISO deterministic analysis).

5. **Forecast Error** – Operational forecast errors are based on historical errors for load, wind, and solar.

All other inputs will be deterministic and will match scoping memo assumptions*, including non-CAISO area inputs, fuel prices, and GHG prices.

*Any deviations from the scoping memo will be recorded and reported.

A planning reserve margin and capacity analysis will be performed to help understand system reliability.

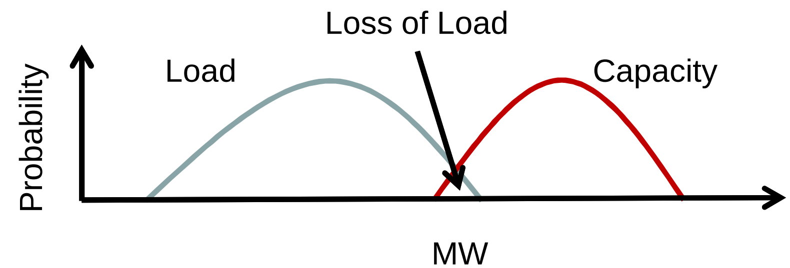
Capacity Analysis

Two capacity analyses are performed to determine if additional capacity is needed to satisfy traditional planning standards:

Planning Reserve Margin

$$\frac{\textit{Dependable Capacity}}{\textit{Peak Load}} > \textit{115\%*}$$

Capacity vs Load Analysis



The results will be used to:

- Understand how production simulation results compare to traditional metrics
- Provide transparency to the stochastic and deterministic inputs for the scenario.
- Provide evaluation of PRM

*The Commission has adopted a PRM range of 15%-17%

A large number of samples will be run through PLEXOS to determine if there are any system deficiencies.

Simulation Modeling

- Production simulation modeling will be able to account for multiple factors that are not considered in the Capacity Analysis, including:
  - *Flexibility Needs*
  - *Ancillary Service Requirements*
  - *Over-Generation, Exports, and Curtailment*
  - *Economic Implications and Tradeoffs*
  - *Use Limited Resources Operations*
  - *System Level Transmission Constraints*
  - *Forecast Error*
- Any increased needs found through Production Simulation Modeling do NOT imply it is a flexibility need, but rather a need resulting from not looking at all factors in the traditional metrics.
- The tool can determine MW Need and Type, however, that will be performed in the second phase of this LTPP proceeding.

SCE's analysis will produce additional metrics to help understand scenario implications, including Over-Generation and Greenhouse Gas Emissions.

Result Metrics

SCE's analysis will produce metrics to help inform the understanding of the different planning scenarios:

- **Stage 3 System Emergencies**
- **Other System Reliability Violations**
- **Over-Generation Conditions / Exports /Curtailment**
- **Downward Flexibility Need**
- **Model Comparison Efforts**

2014 LTPP Analysis

- Overview
- Over-Generation
- Hydro
- Net Load Following and Forecast Error
- Convergence Analysis

Over-Generation tradeoffs will be analyzed outside of production simulation modeling.

Over-Generation Analysis

1. Over-Generation is captured in the analysis by:
   - Limiting CAISO to No Net Exports
   - Using a $100 penalty* for all over-generation (dump) energy
   - Downward ramping shortfall

2. Production Simulation Results will be analyzed outside of the model to see what the characteristics of Over-Generation are and the potential for economic solutions to resolve any identified issues, including:
   - **Export** of energy at a possible negative price
   - **Low / Negative Market Prices** to incent less generation or more load during stress hours
   - **Curtailment** of generation
   - **Storage** to shift energy to periods of higher demand

*$100 estimates the cost of renewable energy curtailment

2014 LTPP Analysis

- Overview
- Over-Generation
- Hydro
- Net Load Following and Forecast Error
- Convergence Analysis

Historic hydro generation was used to model a wet, normal, and dry year

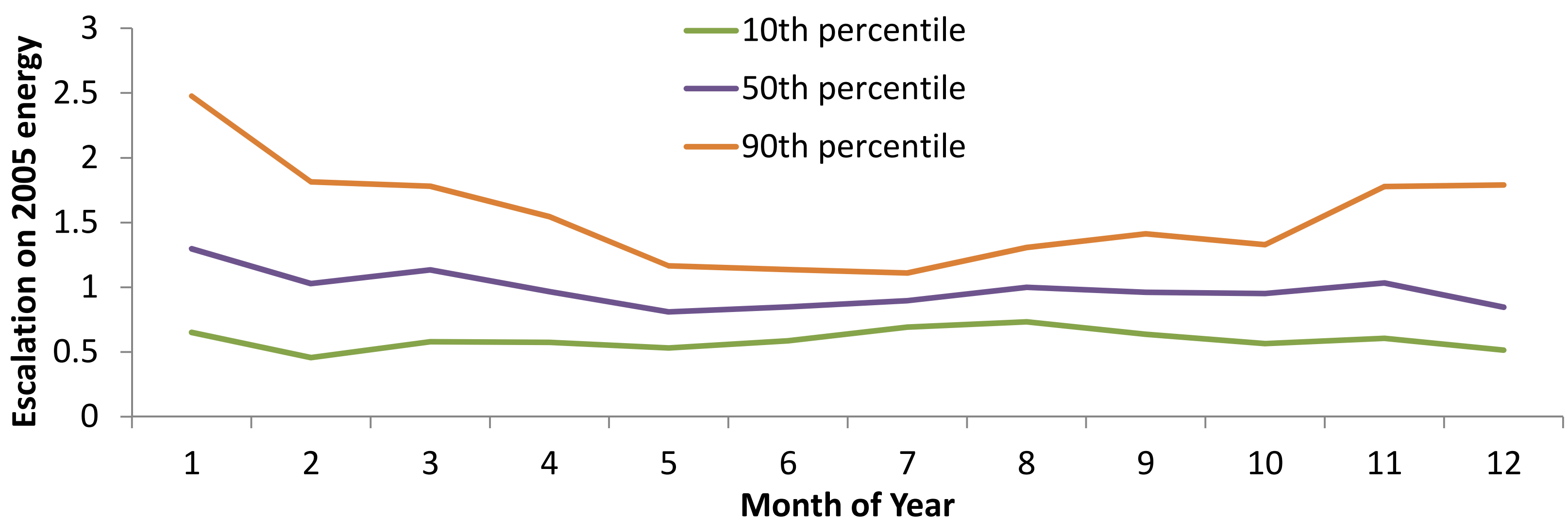
Hydro Variability

Illustrative Only

1. Historic 2005 energy targets were used for 2010 and 2012 LTPP

2. 40+ years of historic hydro generation from EIA* give a distribution of potential hydro energy

3. 2005 energy targets are escalated to model wet, normal, and dry year hydro conditions based on the 10th, 50th, and 90th percentiles of historic data



*Energy Information Authority

2014 LTPP Analysis

- Overview
- Over-Generation
- Hydro
- Net Load Following and Forecast Error
- Convergence Analysis

Net Load Following will be split into two parts in order to capture how reserve shortfall affects system reliability.

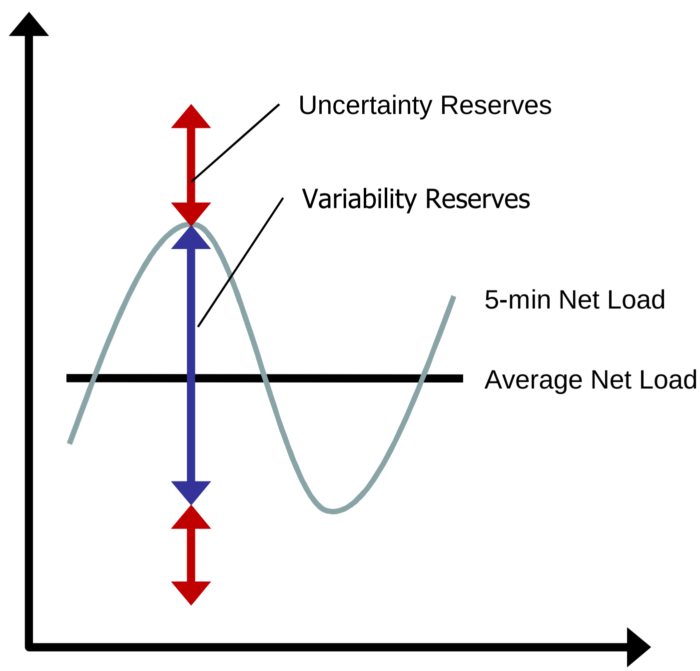
Net Load Following

Net Load Following will be split into two parts:

1) **Variability**
    1) The ramping requirements resulting from the 5-minute net load draw.
    2) This ramp may result in reliability violations if not met

2) **Uncertainty (Forecast Error)**
    1) Requirement resulting from an incorrect forecast during the hour ahead timeframe.
    2) Requirement forecasted using historical forecast error for load, wind, and solar generation.
    3) Ramp may or may not result in reliability violations if not met

Net Load Following Illustration

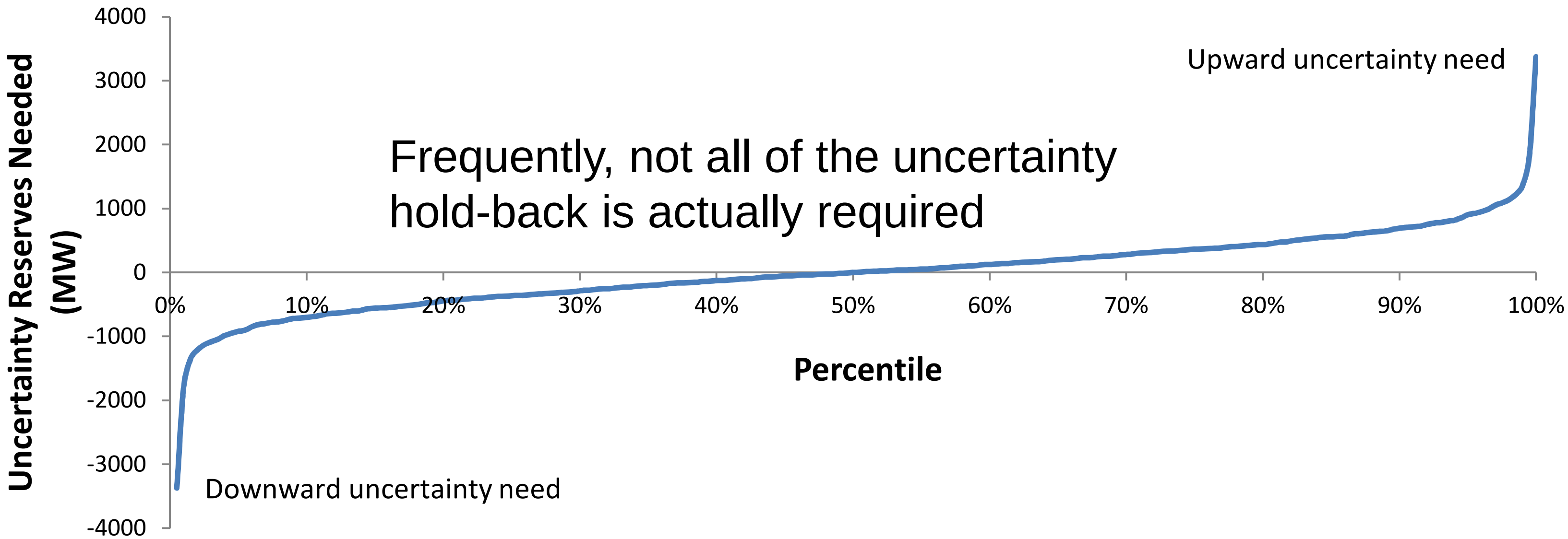


Uncertainty / Forecast Error Shortfall Implications

Illustrative Only

Un-met uncertainty reserves do not necessarily imply a stage 3 emergency:

Illustrative Example of Probability of Needing Upward Forecast Error Reserves



2014 LTPP Analysis

- Overview
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- Convergence Analysis

Convergence Analysis – *"Are we there yet?"*

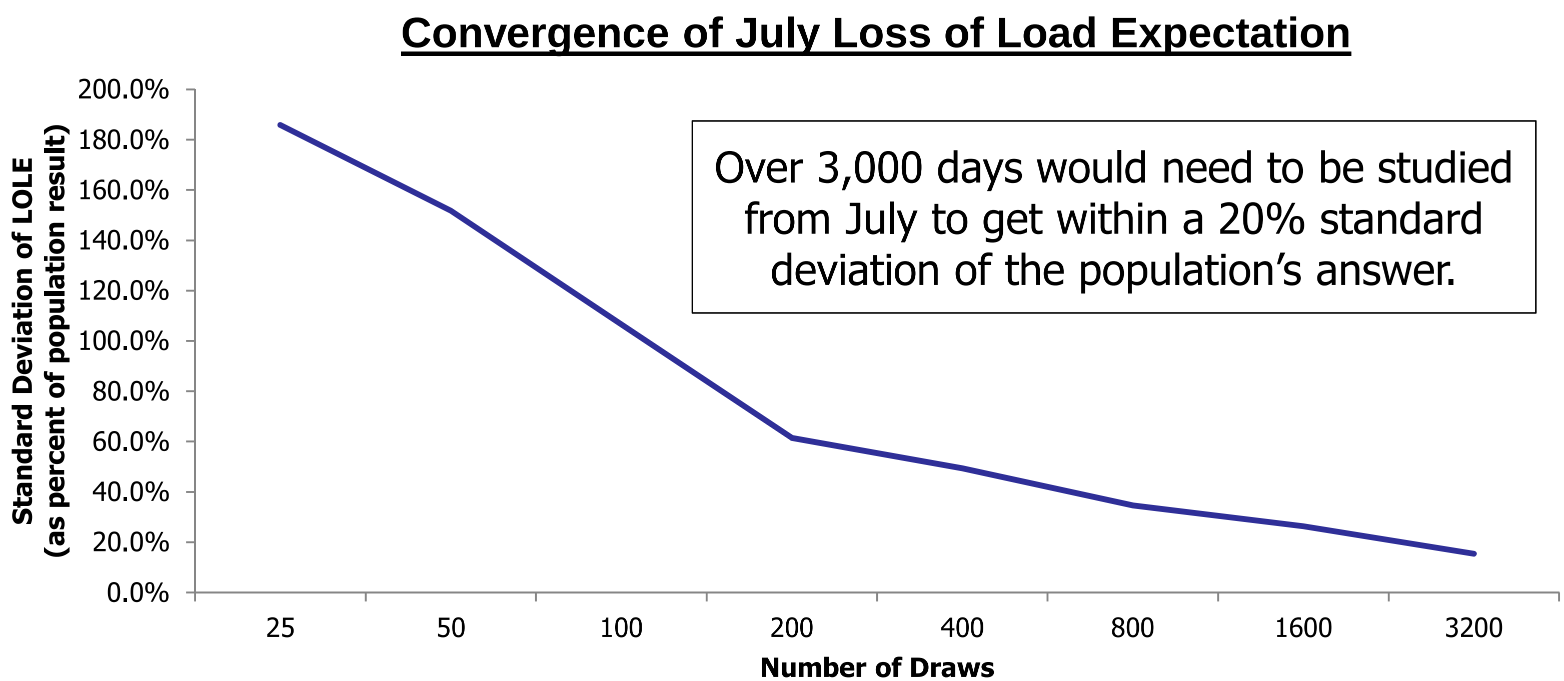
Convergence Analysis evaluates how well the drawn samples represent the whole population. As more samples are drawn, the samples give a more accurate representation of the population.

Example: Probability of a Coin Flip being "HEADS"

Number of Coin Flips	1	10	100	1000
Number of Heads	1	6	56	499
Implied Probability of Heads	100.0%	60.0%	56.0%	49.9%

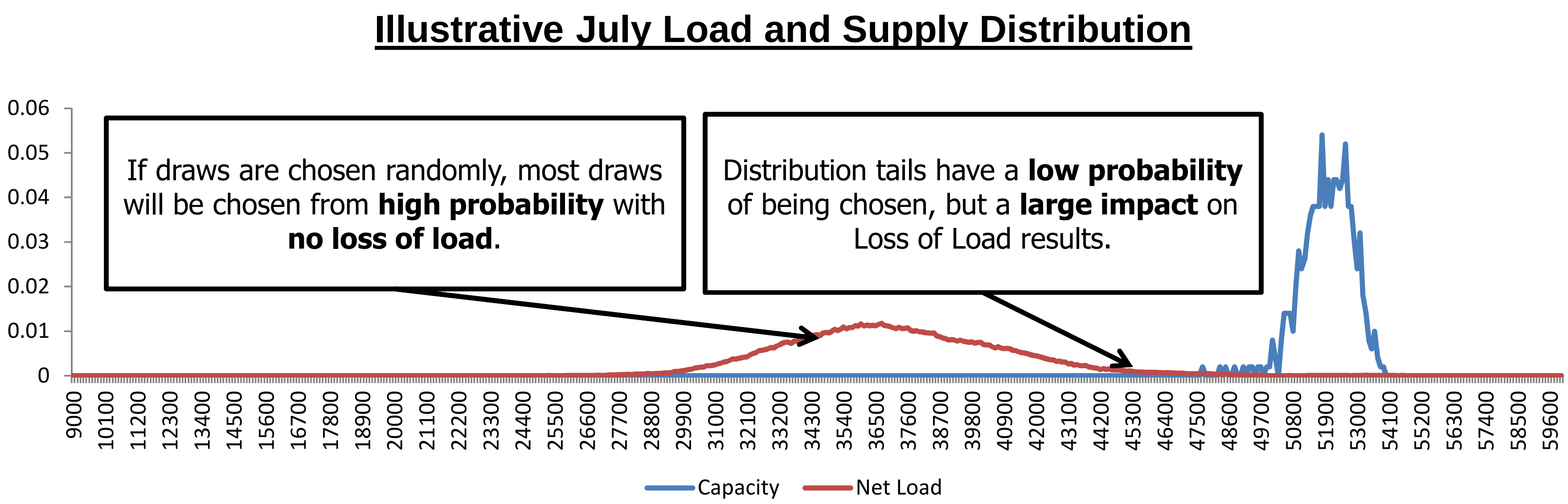
Convergence Analysis for Capacity Shortfall

A Monte Carlo simulation was performed for the Capacity vs Load Analysis to see how well results converge towards the true population's answer.



Completely random sampling will tend to test days that do not have loss of load.

Analysis Convergence Challenges



Stratification is used so that critical areas are sampled with higher frequency (with results weighted appropriately) in order for convergence to be reached with fewer draws.

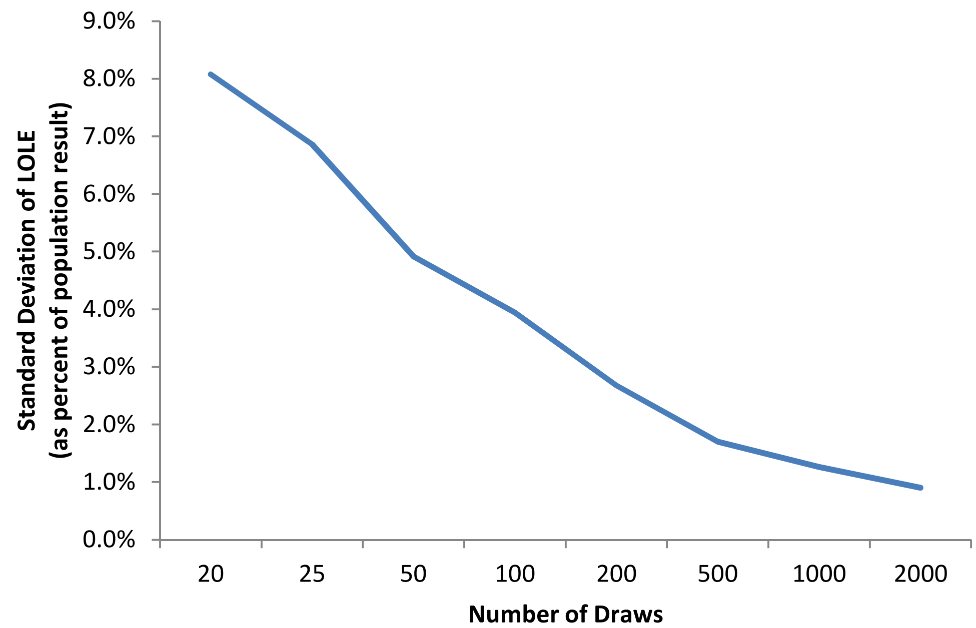
Stratification can reduce the number of draws needed for a representative sample.

Stratification Implementation

Example Stratification Implementation

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="6">Net Load Peak - Percentiles</td></tr>
<tr><td>0-25</td><td>25-50</td><td>50-75</td><td>75-95</td><td>95-99</td><td>99-100</td></tr>
<tr><td rowspan="6">Net Load Trough to Peak Ramp - Percentiles</td><td>0-25</td><td colspan="5" rowspan="5">Fewer samples will be chosen from buckets where reliability violations are extremely unlikely to occur.</td><td rowspan="5"></td></tr>
<tr><td>25-50</td></tr>
<tr><td>50-75</td></tr>
<tr><td>75-95</td></tr>
<tr><td>95-99</td></tr>
<tr><td>99-100</td><td colspan="6">More samples will be chosen from buckets where reliability violations have a high probability of occurring</td></tr>
</table>

Example Stratification Convergence Analysis



Stratification allows the model to converge within a 5% standard deviation using only 50 draws (Over 3,000 draws were needed to reach a 20% standard deviation without stratification).

Next Steps and Timeline

Next Steps and Timeline

- Analyze at least one scenario for Phase 1A of the 2014 LTPP by August of 2014
- Present final results at a CPUC Workshop
- Depending on the outcome of Phase 1A, determine the MW type and magnitude for any identified resource within Phase 1B of the 2014 LTPP Proceeding.

Thank You!

Questions / Comments:

Megan.Mao@sce.com

The ISO 2014 LTPP System Flexibility Study

CPUC LTPP Workshop
June 6, 2014

Shucheng Liu, Ph.D.
Principal, Market Development

About the ISO 2014 Long-Term Procurement Plan (LTPP) system flexibility study

- The ISO conducts a system flexibility study according to the Planning Assumptions and Scenarios as determined in the CPUC May 14, 2014 ruling (13-12-010).

    1) Trajectory scenario
    2) High Load scenario
    3) Expanded Preferred Resources scenario
    4) 40% RPS in 2024 scenario
    5) Trajectory without Diablo Canyon sensitivity

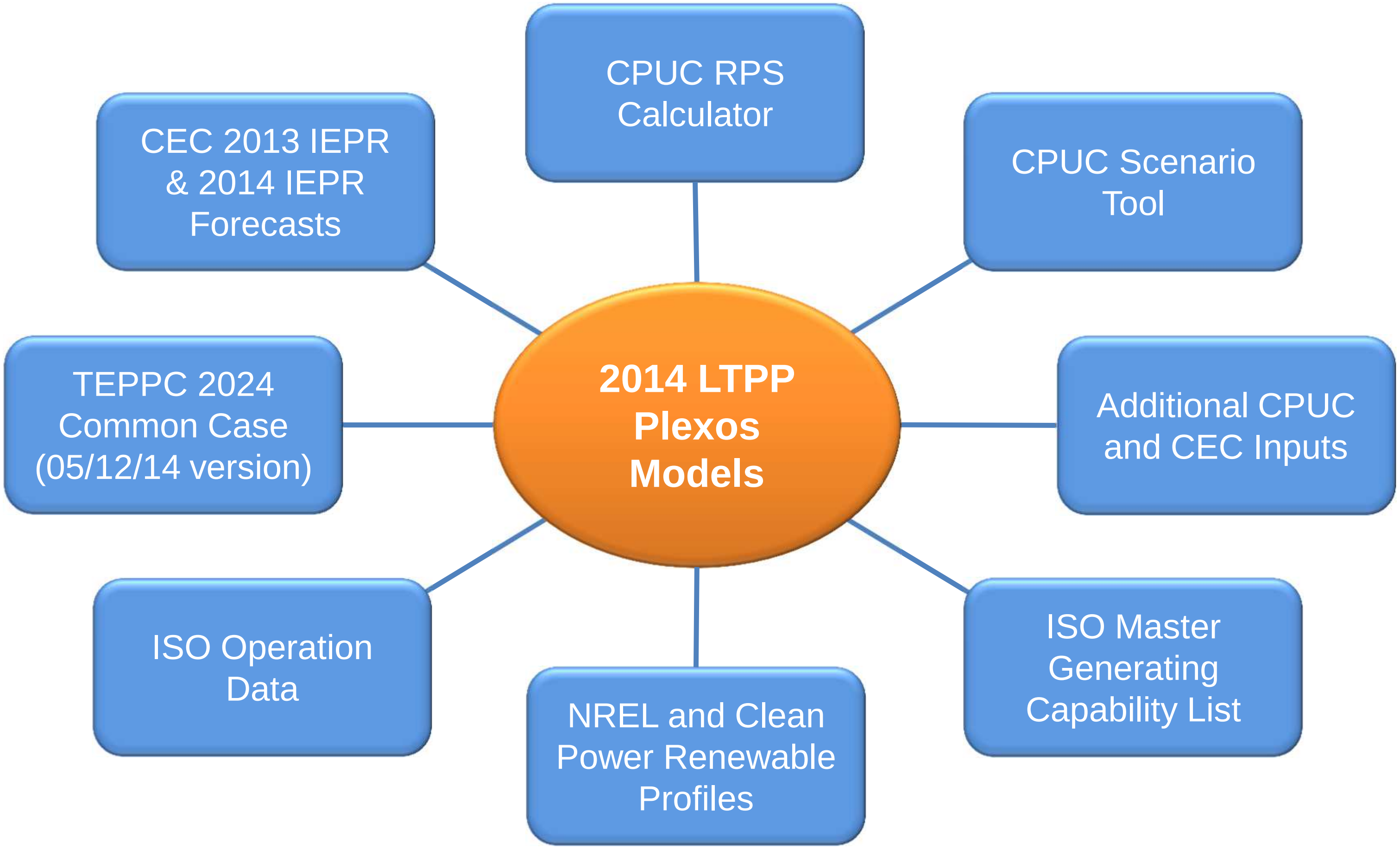
- The study uses both deterministic and stochastic production simulation models.

Agenda

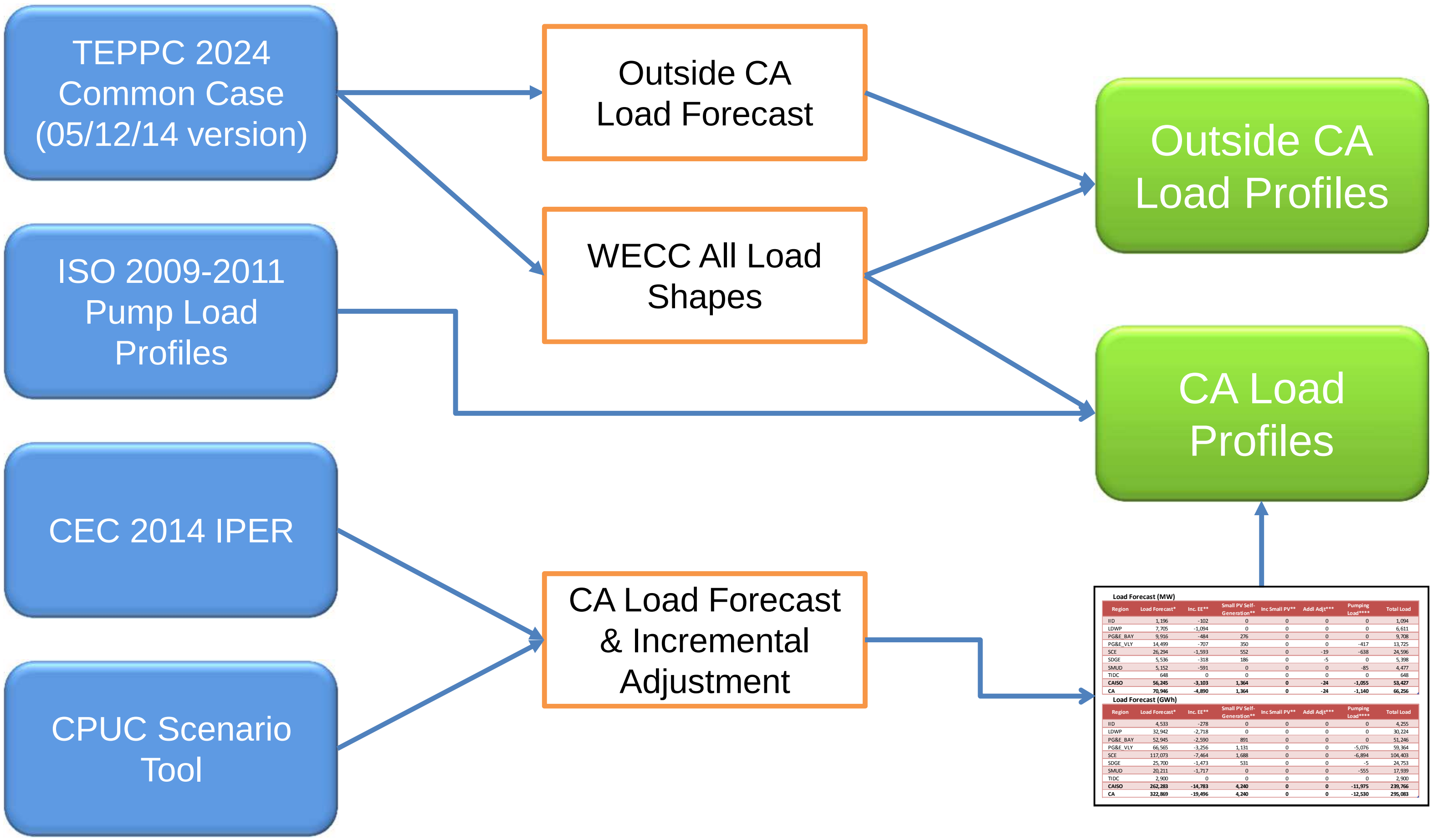
- Model data sources
- Scenario assumption comparison
- Other common assumptions
- Concepts of the ISO stochastic simulation model

Model Data Sources

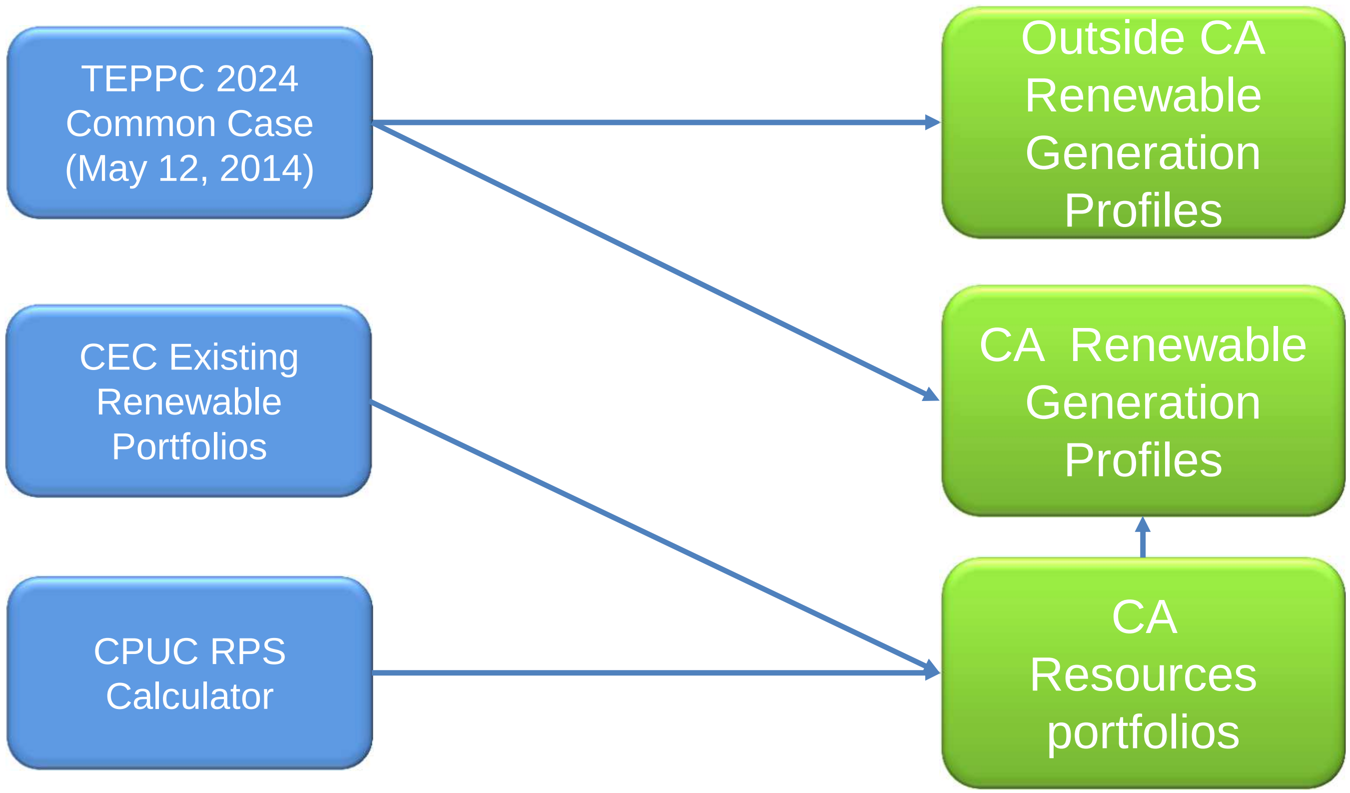
The Plexos production cost simulation models use data from multiple sources.



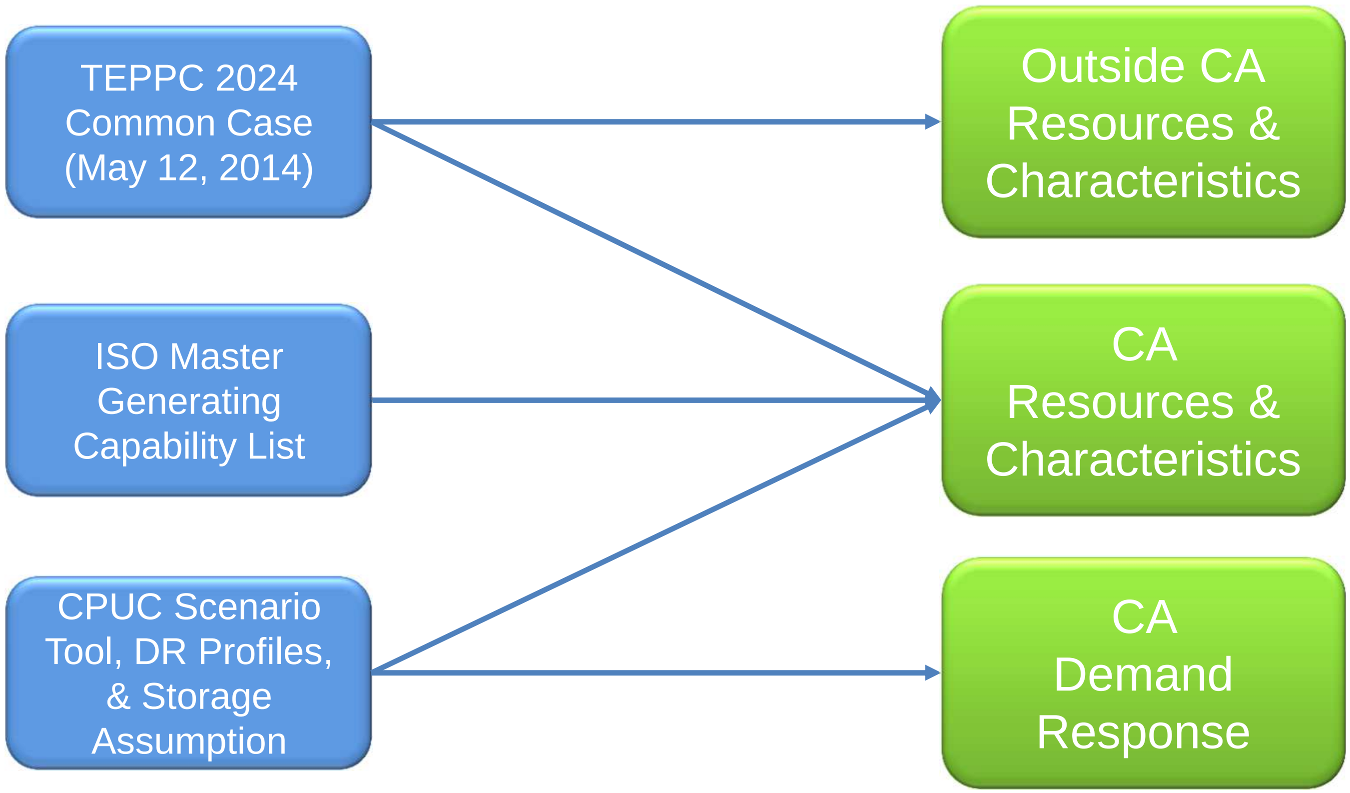
Load forecasts and load shapes are drawn from several data sources.



California renewable generation portfolios follow the CPUC scenario definitions.



Generation resource information is primarily taken from TEPPC 2024 Common Case.



Scenario Assumption Comparison

Aggregated demand and supply

CPUC Scenario Tool

CAISO-2024	Trajectory	High Load	Expanded Preferred Resources	40% RPS in 2024
Demand (MW) *				
IEPR Net Load	56,044	59,006	56,044	56,044
AA-EE	5,042	5,042	8,286	5,042
Managed Demand Net Load	51,003	53,964	47,758	51,003
BTM resources modeled as Supply (MW)				
1: Inc. Small PV	0	0	1,647	0
2: Inc. Demand-side CHP	0	0	1,832	0
Supply (MW)				
3: Existing Resources	51,878	51,878	51,878	51,878
4: Resource Additions	7,468	8,440	9,202	11,754
Non-RPS (Conventional Expected)	329	329	329	329
RPS	5,939	6,911	7,673	10,225
Authorized Procurement	1,200	1,200	1,200	1,200
5: Imports	13,396	13,396	13,396	13,396
6: Inc. Supply-side CHP	0	0	0	0
7: Dispatchable DR	2,176	2,176	2,176	2,176
8: Energy Storage Target	913	913	913	913
9: Energy Storage Other	0	0	0	0
10: Resource Retirements	13,708	13,708	13,708	13,708
OTC Non Nuclear	11,685	11,685	11,685	11,685
OTC Nuclear	0	0	0	0
Solar + Wind	0	0	0	0
Geothermal + Biomass	0	0	0	0
Hydro + Pump	0	0	0	0
Other (non-OTC thermal/cogen/other)	2,023	2,023	2,023	2,023
Net Supply = sum[1:9] - 10	62,122	63,094	67,335	66,408

Note: the load is coincident peak

Trajectory scenario load forecast and adjustments

Trajectory	Load Forecast*	AAEE**	Embedded Small PV**	Pumping Load***	Total Load
Load Forecast (MW)					
IID	1,241	0	0	0	1,241
LDWP	7,208	0	0	0	7,208
PG&E_BAY	9,614	-998	499	0	9,115
PG&E_VLY	15,569	-1,292	646	-753	14,170
SCE	26,882	-2,308	732	-683	24,623
SDGE	5,357	-567	251	0	5,041
SMUD	5,240	0	0	-143	5,097
TIDC	721	0	0	0	721
CAISO	**57,422**	**-5,165**	**2,127**	**-1,436**	**52,949**
CA	**71,833**	**-5,165**	**2,127**	**-1,578**	**67,216**
Load Forecast (GWh)					
IID	4,777	0	0	0	4,777
LDWP	32,618	0	0	0	32,618
PG&E_BAY	51,511	-4,134	1,696	0	49,073
PG&E_VLY	68,832	-5,767	2,366	-4,556	60,875
SCE	119,137	-10,239	2,696	-5,700	105,894
SDGE	24,271	-2,425	958	0	22,805
SMUD	20,117	0	0	-1,455	18,662
TIDC	2,978	0	0	0	2,978
CAISO	**263,751**	**-22,565**	**7,716**	**-10,256**	**238,646**
CA	**324,241**	**-22,565**	**7,716**	**-11,711**	**297,681**

Note: this is non-coincident peak

* CEC 2014 IPER Form 1.5a and 1.5b. All scenarios have Mid (1-in-2) except High Load scenario, which has High (1-in-2) forecast

** CEC 2014 IPER

*** CPUC Scenario Tool and 2009-2011 average of ISO operation data. MW values are pump loads at peak load hours of the regions.

High Load scenario load forecast and adjustments

High Load	Load Forecast*	AAEE**	Embedded Small PV**	Pumping Load***	Total Load
Load Forecast (MW)					
IID	1,299	0	0	0	1,299
LDWP	7,610	0	0	0	7,610
PG&E_BAY	10,378	-998	437	0	9,818
PG&E_VLY	15,971	-1,292	567	-753	14,492
SCE	28,383	-2,308	638	-683	26,030
SDGE	5,724	-567	218	0	5,375
SMUD	5,546	0	0	-143	5,404
TIDC	762	0	0	0	762
CAISO	**60,457**	**-5,165**	**1,859**	**-1,436**	**55,715**
CA	**75,674**	**-5,165**	**1,859**	**-1,578**	**70,789**
Load Forecast (GWh)					
IID	5,048	0	0	0	5,048
LDWP	34,417	0	0	0	34,417
PG&E_BAY	55,072	-4,193	1,484	0	52,362
PG&E_VLY	71,762	-5,708	2,020	-4,556	63,519
SCE	126,306	-10,239	2,313	-5,700	112,680
SDGE	25,959	-2,425	823	0	24,357
SMUD	21,251	0	0	-1,455	19,796
TIDC	3,157	0	0	0	3,157
CAISO	**279,099**	**-22,565**	**6,640**	**-10,256**	**252,918**
CA	**342,972**	**-22,565**	**6,640**	**-11,711**	**315,336**

Note: this is non-coincident peak

* CEC 2014 IPER Form 1.5a and 1.5b. All scenarios have Mid (1-in-2) except High Load scenario, which has High (1-in-2) forecast

** CEC 2014 IPER

*** CPUC Scenario Tool and 2009-2011 average of ISO operation data. MW values are pump loads at peak load hours of the regions.

Expanded Preferred Resources scenario load forecast and adjustments

Expanded Preferred Resources	Load Forecast*	AAEE**	Embedded Small PV**	Pumping Load***	Total Load
Load Forecast (MW)					
IID	1,241	0	0	0	1,241
LDWP	7,208	0	0	0	7,208
PG&E_BAY	9,614	-1,726	516	0	8,404
PG&E_VLY	15,569	-2,099	628	-753	13,345
SCE	26,882	-3,766	732	-683	23,165
SDGE	5,357	-898	251	0	4,710
SMUD	5,240	0	0	-143	5,097
TIDC	721	0	0	0	721
CAISO	**57,422**	**-8,490**	**2,127**	**-1,436**	**49,624**
CA	**71,833**	**-8,490**	**2,127**	**-1,578**	**63,892**
Load Forecast (GWh)					
IID	4,777	0	0	0	4,777
LDWP	32,618	0	0	0	32,618
PG&E_BAY	51,511	-6,667	1,696	0	46,540
PG&E_VLY	68,832	-9,302	2,366	-4,556	57,340
SCE	119,137	-16,339	2,696	-5,700	99,794
SDGE	24,271	-3,761	958	0	21,469
SMUD	20,117	0	0	-1,455	18,662
TIDC	2,978	0	0	0	2,978
CAISO	**263,751**	**-36,068**	**7,716**	**-10,256**	**225,143**
CA	**324,241**	**-36,068**	**7,716**	**-11,711**	**284,178**

Note: this is non-coincident peak

* CEC 2014 IPER Form 1.5a and 1.5b. All scenarios have Mid (1-in-2) except High Load scenario, which has High (1-in-2) forecast

** CEC 2014 IPER

*** CPUC Scenario Tool and 2009-2011 average of ISO operation data. MW values are pump loads at peak load hours of the regions.

40% RPS in 2024 scenario load forecast and adjustments

40% RPS in 2024	Load Forecast*	AAEE**	Embedded Small PV**	Pumping Load***	Total Load
Load Forecast (MW)					
IID	1,241	0	0	0	1,241
LDWP	7,208	0	0	0	7,208
PG&E_BAY	9,614	-998	499	0	9,115
PG&E_VLY	15,569	-1,292	646	-753	14,170
SCE	26,882	-2,308	732	-683	24,623
SDGE	5,357	-567	251	0	5,041
SMUD	5,240	0	0	-143	5,097
TIDC	721	0	0	0	721
CAISO	**57,422**	**-5,165**	**2,127**	**-1,436**	**52,949**
CA	**71,833**	**-5,165**	**2,127**	**-1,578**	**67,216**
Load Forecast (GWh)					
IID	4,777	0	0	0	4,777
LDWP	32,618	0	0	0	32,618
PG&E_BAY	51,511	-4,134	1,696	0	49,073
PG&E_VLY	68,832	-5,767	2,366	-4,556	60,875
SCE	119,137	-10,239	2,696	-5,700	105,894
SDGE	24,271	-2,425	958	0	22,805
SMUD	20,117	0	0	-1,455	18,662
TIDC	2,978	0	0	0	2,978
CAISO	**263,751**	**-22,565**	**7,716**	**-10,256**	**238,646**
CA	**324,241**	**-22,565**	**7,716**	**-11,711**	**297,681**

Note: this is non-coincident peak

* CEC 2014 IPER Form 1.5a and 1.5b. All scenarios have Mid (1-in-2) except High Load scenario, which has High (1-in-2) forecast

** CEC 2014 IPER

*** CPUC Scenario Tool and 2009-2011 average of ISO operation data. MW values are pump loads at peak load hours of the regions.

California RPS net short calculation

CPUC RPS Calculator

	All Values in GWh for Year 2024	Formula	Trajectory	High Load	Expanded Preferred Resources	40% RPS in 2024
1	Statewide Retail Sales - Dec 2013 IEPR		300,516	317,781	300,516	300,516
2	Non RPS Deliveries (CDWR, WAPA, MWD)		9,272	9,272	9,272	9,272
3	Retail Sales for RPS	3=1-2	291,244	308,509	291,244	291,244
4	Additional Energy Efficiency		24,410	24,410	36,713	24,410
5	Additional Rooftop PV		0	0	5,360	0
6	Additional Combined Heat and Power		0	0	16,016	0
7	Adjusted Statewide Retail Sales for RPS	7=3-4-5-6	266,834	284,099	233,156	266,834
8	**Total Renewable Energy Needed For RPS**	8=7*33% or 7*40%	**88,055**	**93,753**	**93,262**	**106,734**
	Existing and Expected Renewable Generation					
9	Total In-State Renewable Generation		42,909	42,909	42,909	42,909
10	Total Out-of-State Renewable Generation		10,639	10,639	10,639	10,639
11	Procured DG (not handled in Calculator)		2,204	2,204	2,204	2,204
12	SB 1122 (250 MW of Biogas)		1,753	1,753	1,753	1,753
13	**Total Existing Renewable Generation for CA RPS**	13=9+10+11+12	**57,504**	**57,504**	**57,504**	**57,504**
14	**Total RE Net Short to meet 33% RPS In 2022 (GWh)**	14=8-13	**30,551**	**36,249**	**35,758**	**49,230**

Source: CPUC RPS Calculator

California RPS renewable portfolios

Additional CPUC and CEC Inputs

CPUC RPS Calculator

	Biomass	Geothermal	Small Hydro	Solar (PV/Thermal)	Large Solar PV	Small Solar PV	Solar Thermal	Wind	Total
Trajectory Scenario									
Capacity (MW)	1,391	3,029	3,017	3,999	7,411	2,074	1,350	10,728	32,998
Energy (GWh)	8,474	15,681	5,334	9,574	17,104	4,178	3,277	24,009	87,630
In-State Energy	7,912	13,645	5,294	8,159	15,215	4,178	3,277	14,755	72,436
Out-State Energy	562	2,036	40	1,415	1,889	0	0	9,253	15,195
High Load Scenario									
Capacity (MW)									
Energy (GWh)									
In-State Energy									
Out-State Energy									
Expanded Preferred Resources Scenario									
Capacity (MW)									
Energy (GWh)									
In-State Energy									
Out-State Energy									
40% RPS in 2024 Scenario									
Capacity (MW)									
Energy (GWh)									
In-State Energy									
Out-State Energy									

To be added

California RPS renewable portfolios – Trajectory scenario

CPUC RPS Calculator

New Large Solar PV

	Capacity (MW)	Energy (GWh)
Crystalline Tracking	1,437	3,432
Thin-Film	5,974	13,672
Total	**7,411**	**17,104**

New Solar Thermal

	Capacity (MW)	Energy (GWh)
Solar Thermal with Storage	150	473
Solar Thermal without Storage	1,200	2,804
Total	**1,350**	**3,277**

70% of out-state RPS renewable generation is imported into California in all scenarios.

Out of State Renewable Import Scheduling Assumption

Dynamic Schedule	15-min Schedule	Hourly Schedule	Unbundled RECs
15%	35%	20%	30%

- Dynamic and Intra-Hour Schedule reflects combination of FERC Order 764 and Energy Imbalance Market
- Dynamic and 15-min schedules may increase volatilities in renewable generation and result in higher Regulation and Load-Following requirements calculated in Step 1

Forecast errors in Step 1 regulation and load following requirement calculation

ISO Operation Data

Solar and Wind Forecast Errors (as percentage of installed capacity)

Scenario	Type	Persistent	Hour	0<=CI<0.2	0.2<=CI<0.5	0.5<=CI<0.8	0.8<=CI<=1
Trajectory	DG PV	t-30 min	H12-16				
Trajectory	Small PV	t-30 min	H12-16				
Trajectory	Large PV	t-30 min	H12-16				
Trajectory	Solar Thermal	t-30 min	H12-16				
Trajectory	Wind	t-30 min	All				
High Load	DG PV	t-30 min	H12-16				
High Load	Small PV	t-30 min	H12-16				
High Load	Large PV	t-30 min	H12-16				
High Load	Solar Thermal	t-30 min	H12-16				
High Load	Wind	t-30 min	All				
Expanded Preferred Resources	DG PV	t-30 min	H12-16				
Expanded Preferred Resources	Small PV	t-30 min	H12-16				
Expanded Preferred Resources	Large PV	t-30 min	H12-16				
Expanded Preferred Resources	Solar Thermal	t-30 min	H12-16				
Expanded Preferred Resources	Wind	t-30 min	All				
40% RPS in 2024	DG PV	t-30 min	H12-16				
40% RPS in 2024	Small PV	t-30 min	H12-16				
40% RPS in 2024	Large PV	t-30 min	H12-16				
40% RPS in 2024	Solar Thermal	t-30 min	H12-16				
40% RPS in 2024	Wind	t-30 min	All				

To be added

Load Forecast Errors (standard deviation, MW)*

Scenario	Load	Time	Hour	Spring	Summer	Fall	Winter
All	RTPD	t-30 min	All	228	333	410	252
All	RTD	t-5 min	All	103	189	258	118

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SCIT and California import limits

(MW)	Summer Peak	Summer Off-Peak	Non-Summer Peak	Non-Summer Off-Peak
Trajectory Scenario				
SCIT Limit				
CA Import Limit				
High Load Scenario				
SCIT Limit				
CA Import Limit				
Expanded Preferred Resources Scenario				
SCIT Limit				
CA Import Limit				
40% RPS in 2024 Scenario				
SCIT Limit				
CA Import Limit				

To be added

Other Common Assumptions

Southern California local capacity resources assumptions*

Additional CPUC and CEC Inputs

- CPUC Track 1 authorized resources
  - SDG&E
    - 3x100 MW GT (Pio Pico) plus 10 MW GT repower
  - SCE
    - 1x900 MW CCGT and 3x100 MW GT
    - 50 MW storage (included in the 1,325 MW total)
    - 400 MW preferred resource not included
- CPUC Track 4 authorized resources
  - Not included

* May 14, 2014 CPUC Assigned Commisioner's Ruling (13-12-010)

Demand response resources triggering prices and availabilities

Additional CPUC and CEC Inputs

Event-Based Demand Response Resources

Utility	Price ($/MWh)	Max Capacity (MW)	Availability	Monthly Energy Limit (GWh)
PG&E	600	424	All Hours	8.5
PG&E	1,000	70	H12-19	
PG&E	1,000	6	H13-20	
PG&E		274	All Hours	
PG&E Total		**773**		**8.5**
SCE	600	1,169	All Hours	23.4
SCE	1,000	9	H12-19	
SCE	1,000	10	H13-20	
SCE		173	All Hours	
SCE Total		**1,361**		**23.4**
SDG&E	600	22	All Hours	0.4
SDG&E	1,000	17	H12-19	
SDG&E	1,000	3	H13-20	
SDG&E Total		**42**		**0.4**
Total		**2,176**		**32.3**

The CPUC storage target assumptions

Additional CPUC and CEC Inputs

- 700 MW transmission plus 213 MW distribution-connected can contribute to ancillary services and load-following
- Round-trip efficiency is 83.33%

	PG&E			SCE			SDG&E			Total
(MW)	2 hours	4 hours	6 hours	2 hours	4 hours	6 hours	2 hours	4 hours	6 hours	
Transmission	124	124	62	124	124	62	32	32	16	700
Distribution	74	74	37	74	74	37	22	22	11	425
Customer	43	43	0	43	43	0	15	15	0	200
Total	241	241	99	241	241	99	69	69	27	1,325

Note: Storage volume is measured as number of hours of discharge at full capacity.

CEC natural gas price forecast

CEC 2013 IEPR & 2014 IEPR Forecasts

- Comparison of natural gas price forecasts for 2012 and 2014 LTPP studies

Natural Gas Price Forecast (2014 $/MMBTU)

	2012 LTPP		2014 LTPP	
	PG&E BB	PG&E LT	PG&E BB	PG&E LT
Jan	4.56	4.73	4.38	4.99
Feb	4.30	4.47	4.43	5.03
Mar	4.21	4.38	4.27	4.86
Apr	4.34	4.50	4.26	4.85
May	4.48	4.64	4.24	4.82
Jun	4.54	4.71	4.29	4.88
Jul	4.62	4.78	4.13	4.70
Aug	4.27	4.44	4.11	4.68
Sep	4.23	4.39	4.01	4.56
Oct	4.39	4.56	4.24	4.82
Nov	4.75	4.91	4.46	5.06
Dec	4.80	4.97	4.63	5.24

CEC CO_2 emission price forecast

CEC 2013 IEPR & 2014 IEPR Forecasts

- $23.27/Mton (or $21.11/Ston) in 2014 dollars for 2014 LTPP study

  vs.

- $24.13/Mton (or $21.89/Ston) in 2012 dollars for 2012 LTPP study

CO_2 emission cost modeling

- In CA as a generation cost adder:

  CO_2 Cost Adder = $23.27/MTon

- In WECC, except CA and BPA, as a CA import hurdle rate (an adder to wheeling charge):

  Hurdle Rate = 0.435 MTons/MWh * 23.27 $/MTon = $10.12 /MWh

- BPA to CA hurdle rate:

  Hurdle Rate = 20% x $10.12 = $2.02/MWh

Refer to ARB rules

http://www.arb.ca.gov/regact/2010/ghg2010/ghgisoratta.pdf

The ISO calculated ramp rates and outage rates

ISO Operation Data

- Ramp rate by capacity size group based on the ISO Master File data
- Planned outage and forced outage rates based on 2006-2010 operation data

The ISO calculated ramp rates and outage rates (cont'd)

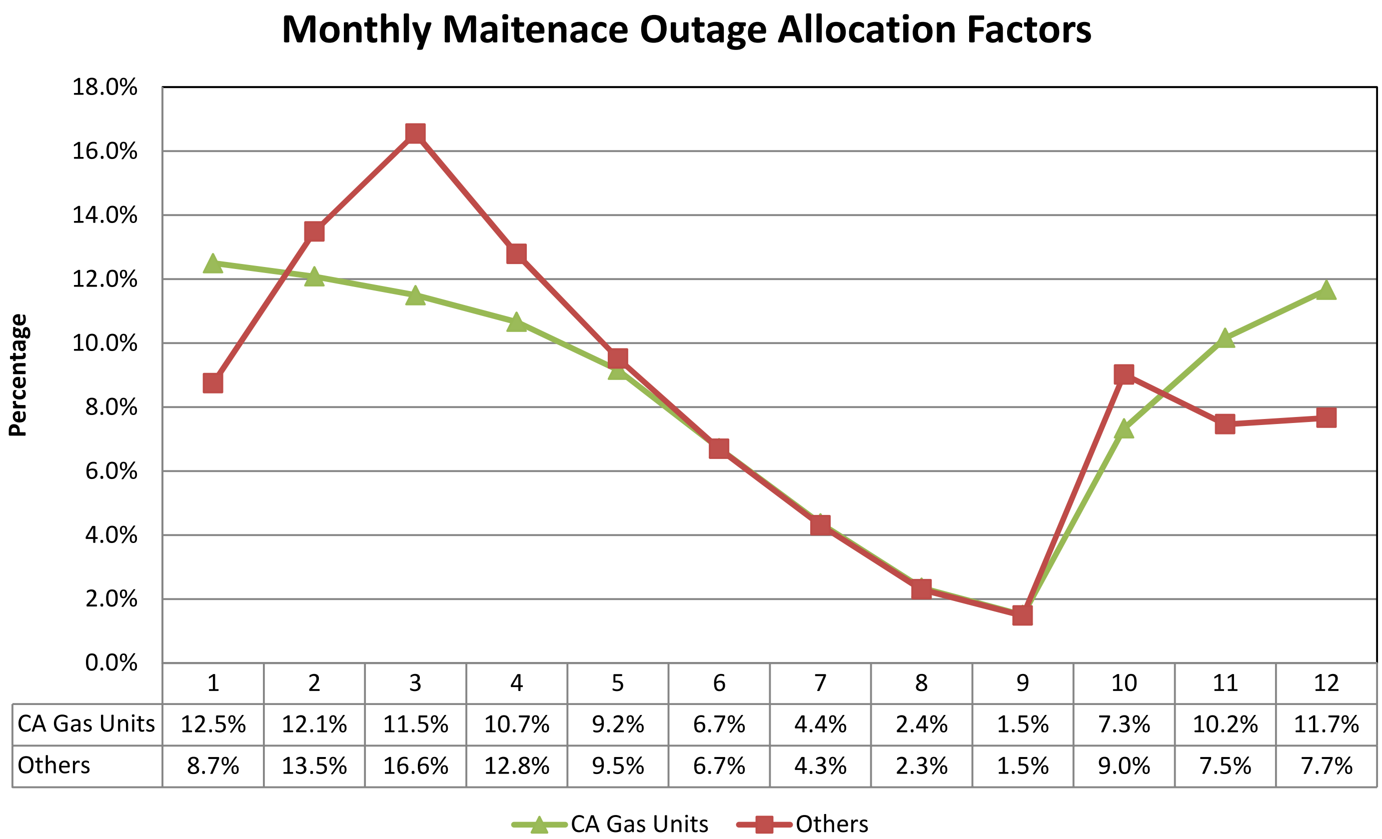
ISO Operation Data

Ramp Rate and Outage Rate of Some Unit Types

Unit Type	Capacity Group 1 Ramp Rate (MW/min)	Capacity Group 2 Ramp Rate (MW/min)	Capacity Group 3 Ramp Rate (MW/min)	Capacity Group 4 Ramp Rate (MW/min)	Planed Outage Rate (%)	Forced Outage Rate (%)
COMBINED CYCLE	CAP_0-200	CAP_200-400	CAP_400-600	CAP_600 ABOVE	6.76	5.23
	6.58	8.44	15.61	15.54		
DIESEL / OIL CT	CAP_50-100				2.85	2.79
	5.00					
GAS STEAM TURBINE	CAP_0-200	CAP_200-400	CAP_400-600	CAP_600 ABOVE	9.11	4.01
	2.79	7.62	4.80	26.66		
GAS TURBINE	CAP_0-50	CAP_50-100	CAP_100-150	CAP_150 ABOVE	4.53	5.82
	9.26	12.32	17.14	19.41		
NUCLEAR	CAP_600 ABOVE				8.16	3.39
	6.98					
PUMPED STORAGE	CAP_0-200	CAP_200-400	CAP_400-600	CAP_600 ABOVE	8.65	6.10
	34.35	46.61	80.80	56.26		

Maintenance outage allocation factors

ISO Operation Data



	1	2	3	4	5	6	7	8	9	10	11	12
CA Gas Units	12.5%	12.1%	11.5%	10.7%	9.2%	6.7%	4.4%	2.4%	1.5%	7.3%	10.2%	11.7%
Others	8.7%	13.5%	16.6%	12.8%	9.5%	6.7%	4.3%	2.3%	1.5%	9.0%	7.5%	7.7%

Reserve and load following requirements assumptions

TEPPC 2024 Common Case (05/12/14 version)

- Operating reserve requirements for all regions
  - Spinning = 3% of load
  - Non-spinning = 3% of load
- Regulation and load following requirements
  - CA regions based on Step 1 calculation
  - Regions outside CA based on TEPPC 2024 Common Case

Transmission path ratings and wheeling charges assumptions

TEPPC 2024 Common Case (05/12/14 version)

- WECC path ratings and wheeling charges
  - TEPPC 2024 Common Case
- Southern California Import Transmission (SCIT) and CA simultaneous import limits
  - SCIT calculation tool
- CA import CO_2 emission cost hurdle rate
  - $10.12/MWh adder to wheeling charge of import into CA (except import from BPA)
  - $2.02/MWh adder to wheeling charge of import from BPA into CA

CA dedicated imports are modeled as must-take.

- Dedicated import includes
  - 100% of CA ownership shares of generation by conventional resources (Hoover, Palo Verde, etc.)
  - 70% of out-of-state RPS renewable generation
- Dedicated import is not subject to the CO_2 emission cost hurdle rate
- Dedicated import energy as well as upward ancillary services and load following provided by resources outside CA are all subject to the CA import limit

The ISO proposes to set a limit on net export.

- Proposing to allow no ISO net export based on
  - Must-take dedicated import from conventional resources
  - Must-take import of 70% out of state RPS renewable generation
  - Lack of a broader range jointly-clearing market

Renewable curtailment modeling assumptions

- Set renewable generation curtailment price to -$300/MWh
- There is no curtailment quantity limit
- Curtailment occurs when there is over-generation
- Energy price will drop to -$300/MWh

Concepts of the ISO Stochastic Simulation Model

General model structure and functions

- The deterministic model with scope reduced to the ISO only plus import and export capability
- Stochastic variables including load, solar, and wind generation, and forced outages
- Chronologic hourly Monte Carlo simulations
  - Each draw is done chronologically for the whole year
  - Simulations can be for the whole year, or for selected months or weeks

General model structure and functions (cont.)

- 5-min economic dispatch for all iterations of selected days with loss of load as verification of the hourly simulations
- Results including
  - Probability distributions of loss of load, its mean value can be compared directly with the 1 day-in-10 years standard
  - Probability distributions of curtailment and over-generation
  - Loss of load, curtailment, and over-generation by iteration for deep analyses

Stochastic variables

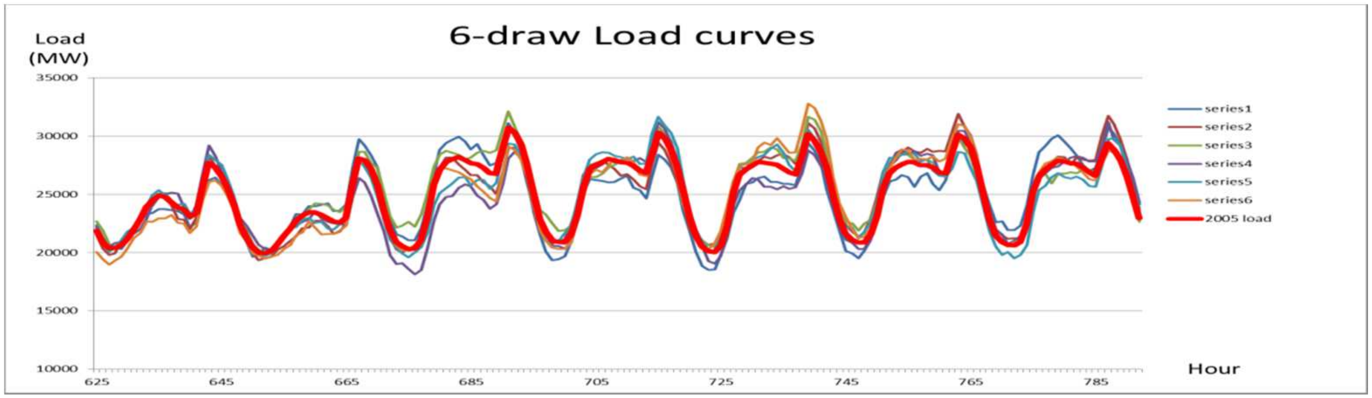
- Load, solar, and wind generation variables are based on a chronological mean-reversion stochastic process

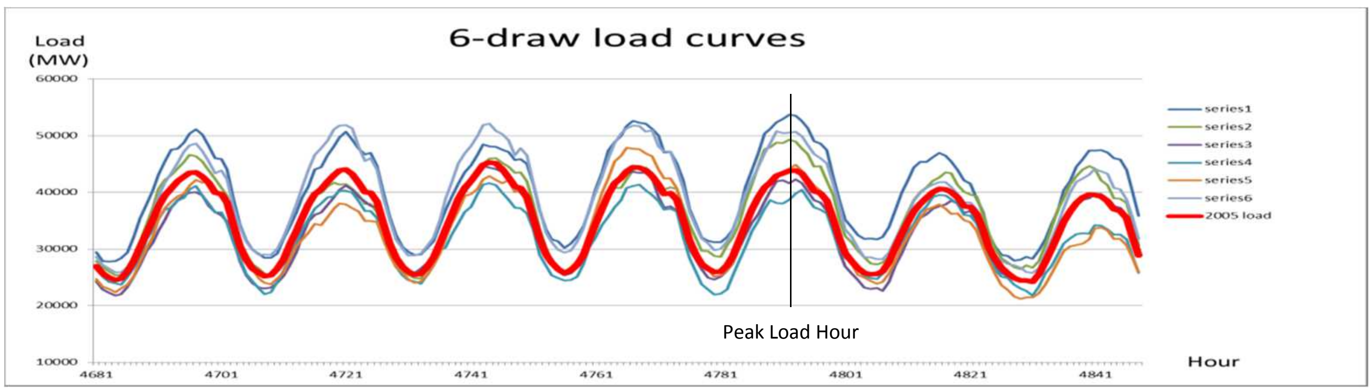
$$X_{t+1} = X_t + \kappa(\mu - X_t) + \varepsilon_{t+1}$$

X_t – current value of the process
μ – long-term mean value of the process
κ – speed of mean reversion
ε_{t+1} – a random shock with zero-mean normal distribution

- Forced outages are generated through regular Monte Carlo draws based on the uniform distribution function

Example of draws of load stochastic variable





- In actual simulations each draw is for the whole year

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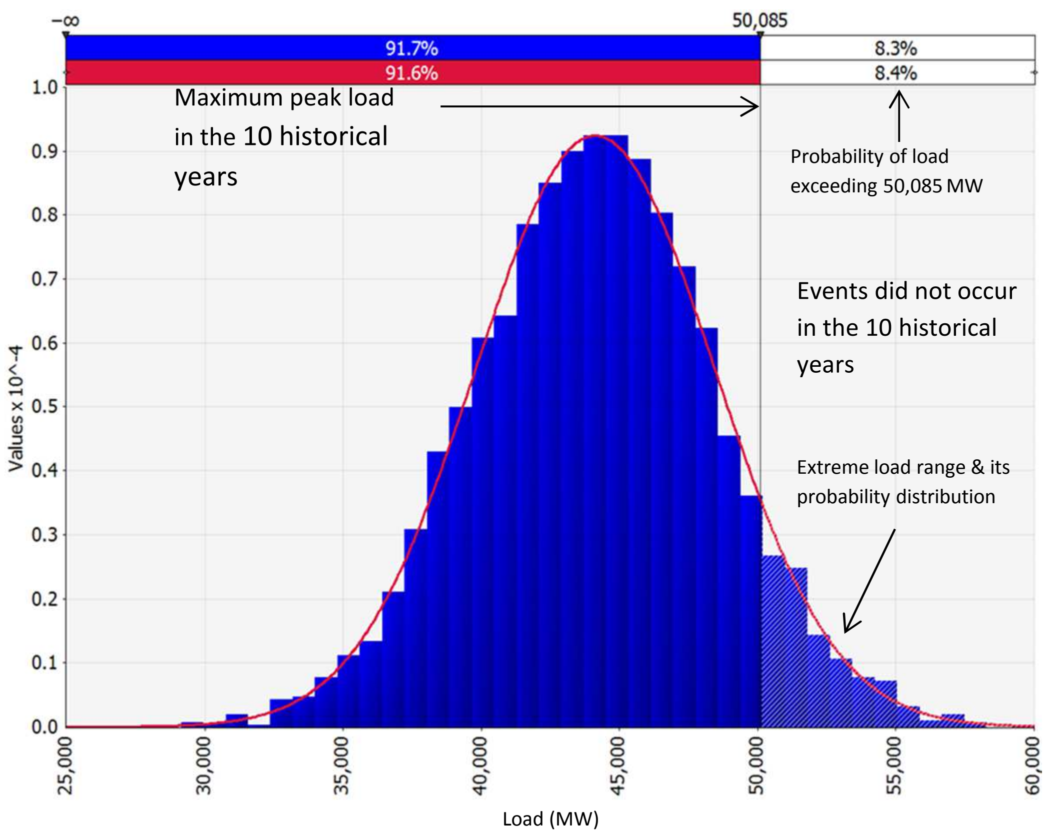
The probability distribution of load at peak hour (see the previous slide).



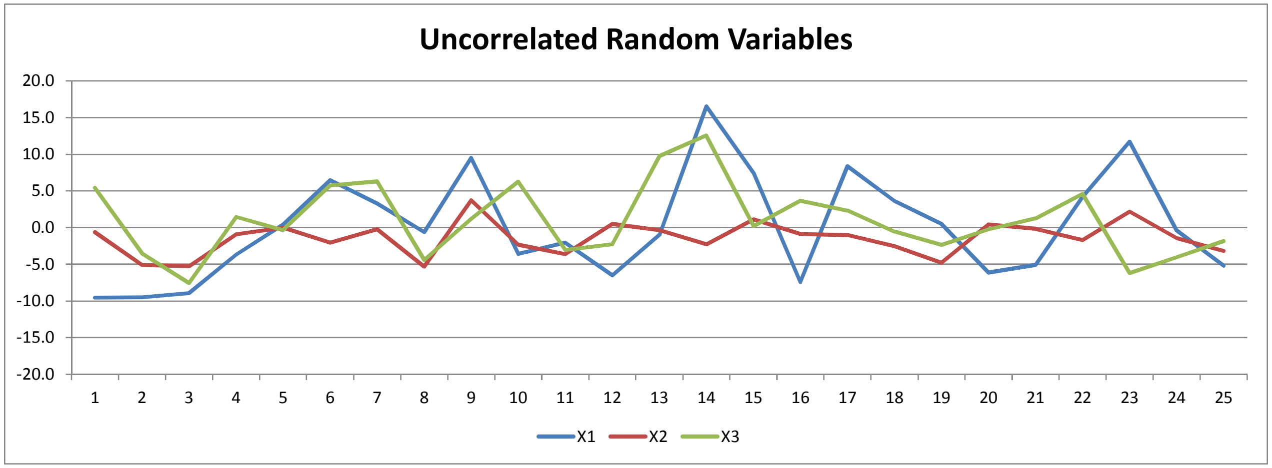
The mean-reversion stochastic process of load is developed based on 2003-2012 10 years historical data.

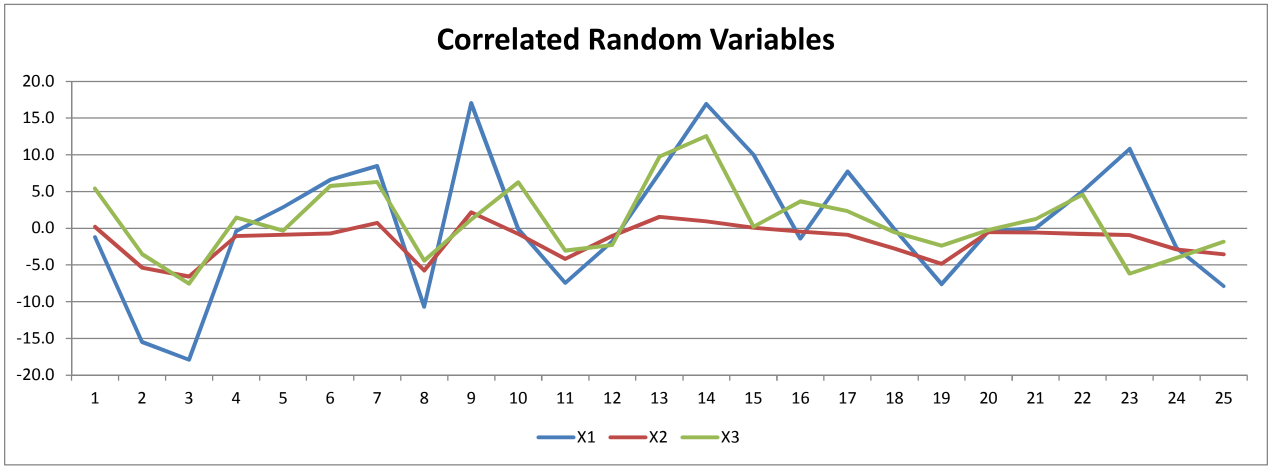
The probability distribution at peak hour captures the extreme load events that did not occur, but are possible in the 10 historical years.

Cross-correlation among the stochastic variables is applied in Monte Carlo simulations.

- The stochastic variables are not independent, but are correlated
- The cross-correlation matrix is calculated based on the multi-year historical data used to develop the stochastic variables
- Cross-correlation is applied in each iteration after the draws of the stochastic variables are done independently to reflect the actual relationship among the variables
- Cross-correlation affects the values of the stochastic variables

An example of the impact of cross-correlation





Correlation Matrix

	X1	X2	X3
X1	1	0.8	0.6
X2	0.8	1	0.8
X3	0.6	0.8	1

Hourly and 5-min simulations are performed where hourly constraints arise.

- Hourly Monte Carlo simulations
  - Chronological simulations with unit commitment and other operational constraints
  - For months or weeks where shortfalls or loss of load, over-generation, or curtailment is likely
  - Reporting hourly simulation results

Hourly and 5-min simulations are performed where hourly constraints arise. (cont.)

- 5-min simulations
  - For selected days with shortfalls or loss of load, over-generation, or curtailment in hourly Monte Carlo simulations
  - 5-min economic dispatch for each of the iterations of the hourly simulations
  - With 5-min load and renewable profiles generated based on hourly profiles of each iteration and real-time forecast errors
  - Without load following requirements

Example of reported stochastic results from hourly Monte Carlo simulations

Category	50th Percentile	75th Percentile	80th Percentile	90th Percentile	95th Percentile	Min	Max	Mean (Expectation)	Standard Deviation	Total Number of Iterations	Number of Iterations with LOL or Curtailment or Over-generation
Loss of Load (LOL)											
- LOL (hour/year)	0	5	8	14	16	1	19	3.33	5.69	200	65
- Loss of Energy (MWh/year)	0	237	341	624	707	42	885	149	257		
- LOL Capacity (MW)	0	57	57	58	58	41	58	16	24		
Loss of Load Due to Lack of Flexibility											
- LOL (hour/year)	0	0	0	2	5	1	10	0.64	1.96	200	26
- Loss of Energy (MWh/year)	0	0	0	68	199	32	437	23	72		
- LOL Capacity (MW)	0	0	0	45	57	32	58	5	14		
Curtailment of Renewable Generation											
- Curtailment (hour/year)	0	3	9	20	26	1	35	4.50	8.85	200	56
- Energy Curtailment (MWh/Year)	0	76	222	437	630	23	838	102	200		
- Capacity Curtailment (MW)	0	30	30	30	30	21	30	7	11		
Over-Generation											
- Over-Generation (hour/year)	0	0	0	9	14	1	21	1.75	4.49	200	36
- Over-Generation Energy (MWh/Year)	0	0	0	126	205	13	311	27	68		
- Over-Generation Capacity (MW)	0	0	0	24	24	13	24	3	8		

Thank you!

Shucheng Liu, Ph.D.
California ISO
sliu@caiso.com